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Cornell University Agricultural Experiment Station,

ITHACA, N. Y.

BOTANICAL DIVISION.

PEACH LEAF-CURL

AND NOTES ON THE

Shot-Hole Effect of Peaches and Plums.

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CORNELL UNIVERSITY, ITHACA, N. Y., February 7, 1899.

THE HONORABLE COMMISSIONER OF AGRICULTURE,
ALBANY, N. Y.

Sir: Of the many diseases with which the fruit-grower has to contend, probably no one has been more generally prevalent during the past season than the peach leaf-curl. Wherever horticultural schools or meetings have been held, questions have come up concerning this disease and its treatment.

Moreover, the greater part of the correspondence referred to the mycologist during the spring of 1898 was in regard to the peach leaf-curl fungus and remedies for the same; fortunately, experiments relative to preventive treatment were already under way.

In this bulletin, Mr. Duggar has given a brief and clear account of the fungus causing the leaf-curl, and he has outlined a treatment which, under difficult conditions, has proved most satisfactory. The peach leaf-curl is one of the three great enemies of the peach-growing industry and like the other two, the yellows and the borer, if neglected or if treated unintelligently, the orchard soon becomes unprofitable, and finally is entirely destroyed.

I. P. ROBERTS, Director.

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PEACH LEAF-CURL AND NOTES ON THE SHOT-HOLE EFFECT OF PEACHES AND PLUMS.

I. Peach Leaf-Curl.*

a. General Remarks.

In bulletin 73 of this Experiment Station a complete account was given of the fungi causing leaf-curl and plum-pockets on many members of the genus Prunus. In the present discussion of the leaf-curl of the peach it will be unnecessary to go into technical details; but in order, as far as possible, to have a reason for that which is done, or recommended, a general account of the life history of the fungus must be included.

Peach leaf-curl is a disease which has long been known to the orchardist as well as to the botanist; and since the seasons of 1897 and 1898, there are probably very few peach growers in the state who are unfamiliar with the disease. The inquiries received during the past spring concerning this disease were so numerous that it has seemed important to give to the growers the results of the work of a single season, along with those results which have been elsewhere obtained. Many of the inquiries have sought a remedy only, but still others have desired a knowledge of the cause; and a general treatment of the subject is necessary.

b. Appearance of the Disease.

Peach leaves affected with the curl can often be detected as soon as the leaf buds have opened to a slight extent. A roughened surface of the young leaf, and an excess of coloring are usually the first indications. As the young leaves rapidly assume their normal size, this curling and arching of the blades is more prominent. Sometimes there is distortion in a small area only, and again the entire blade may be affected. The curling of the edges of the leaves may be upward or downward, or the

* *Exoascus deformans* (Berk.) Fuckel.

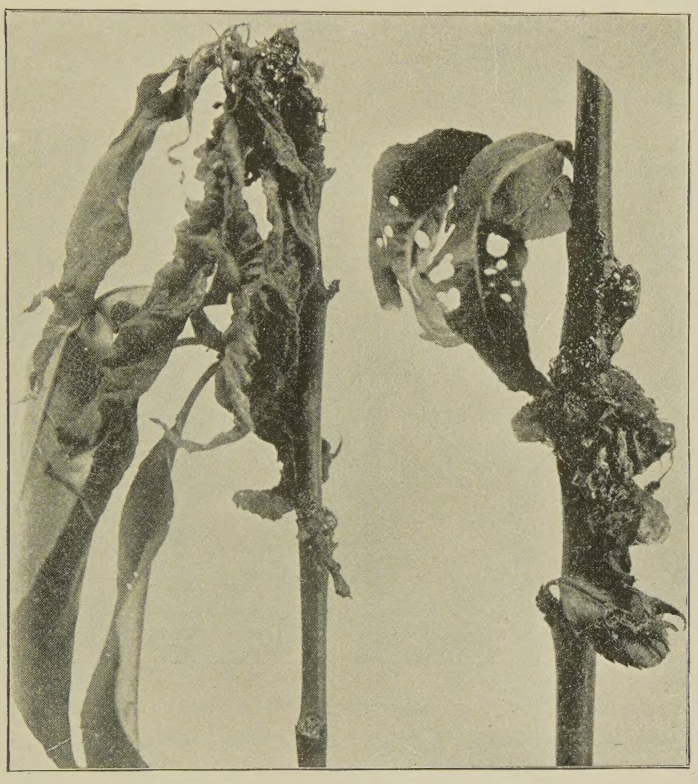
upper surface of the leaf may be gradually arched from base to tip. When the leaf is full grown, the diseased areas may be reddish green ; but usually the green color is largely lost and a pale discoloration characterizes diseased parts. The frontispiece and

64.—*A terminal shoot with both leaves and twig affected by the leaf-curl fungus.*

figure 64 show the appearance of the disease on a cluster of leaves terminating a shoot. Figure 64 also shows another point to be observed. Not only are leaf and leaf-stalk affected, but the terminal part of the shoot becomes much enlarged, and also pale in color. The fungus is then thoroughly established in

the tip of the branch, and the significance of this is apparent later on.

The leaves soon become grayish or mealy in appearance. This appearance is due to the fact that the fungus is fruiting,



65 —*Peach curl and gummosis.*

producing the spores which are to disseminate the disease. After the grayish color appears, the affected leaves gradually dry up and fall off. In this latitude the defoliation from such injuries usually occurs late in June.

In the late stages of this curl disease, as with some other peach diseases, gummy exudations are often noted on those twigs which are enlarged by the fungus; or these may occur even on

the large branches where a diseased cluster of leaves has been attached. Figure 65 shows the condition often called gummosis.

Defoliation of the entire tree does not necessarily mean the death of the tree; but it does mean the death of many twigs, and lessened vitality. New buds, or rather some of the sleeping or dormant buds open and the tree attempts to supply itself with new and healthy foliage. It is very seldom that this fresh foliage is badly affected by the curl; and it is possible to account

a *b* *c* *d*

66.—*a, healthy twig; b and c, twigs in which the leaf-curl fungus is wintering; and d, twig killed by the fungus.*

for whatever curl is now evident as having come directly from diseased buds or twigs.

The new shoot growing out from a diseased terminal bud may grow entirely out of the disease, but the swollen part remains below. Thus, when the season's growth is done and the autumn at hand, these swollen areas may mark out the recovery of shoots; but they also indicate where the fungus rests; and they are warnings of danger for another season. Figure 66, *b* and *c*,

show the appearance of twigs in which the fungus is wintering; *a*, a twig of the same age which is perfectly normal; and *d*, a twig killed by the presence of the fungus in its tip.

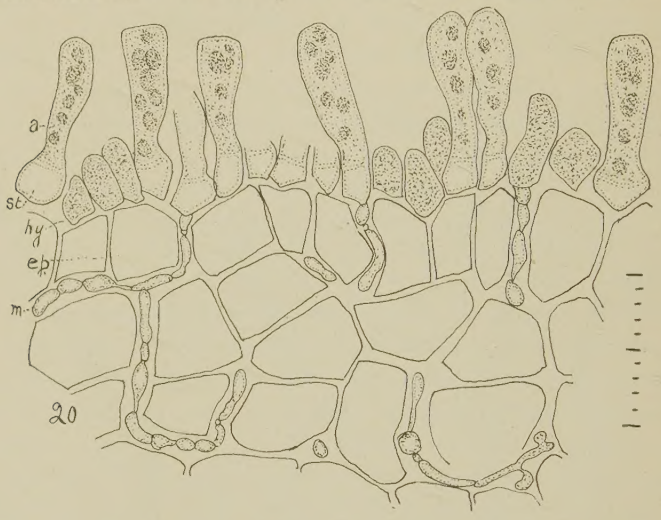
c. Life History of the Fungus.

In this latitude it is usually the latter part of May that the curl is most pronounced, and the grayish appearance is evident soon afterward on all diseased leaves, and on both surfaces of such leaves. The surface is evidently covered with a dense close growth, somewhat mould-like in character. As previously mentioned, the fungus which causes the curl is then fruiting, forming the spores which are to disseminate the disease; but this cannot be seen by the eye alone. Examining under the microscope some of the close growth scraped from the surface of diseased areas, numerous short, erect, thread-like growths (fertile hyphae) will be evident, as in figure 67. Close examination at the time that the fungus is mature shows that these erect hyphae are sac-like in appearance (the asci), and they usually contain eight oval bodies called the spores. In the asci the spores may sprout or bud, forming numerous conidia. After these spores or conidia are mature, they are soon set free from the sac-like structures; and being so minute and light, they are ready to be borne about by the wind. When they fall upon vulnerable parts of other trees, they are in readiness to grow into the tissue and to produce the disease again.

The fruit of the fungus is produced on the surface of the leaf, but the true vegetative state of the fungus is within the tissues of the leaf and of the young shoots. The threads, or filaments, which make up this vegetative state pass in between the cells of the leaf, and it is the irritation due to the presence of these fungous filaments (the mycelium) which causes the leaf to become distorted in form. Passing into the young shoot, the fungus is in a condition to pass the winter in situ, provided the twig lives, without having to trust to the fortune of winds and rains, as is the case with the spore.

It is unfortunate that the exact fate of the more fortunate spores is not known. Since the second growth of leaves is not badly infested by the curl, the spores do not produce the disease

again immediately, it seems. One of two possibilities is then open; either (1) to germinate immediately and infect the buds which will open the next season; or (2) to be hidden away about the twigs, in the bud scales, or even on the ground about the tree, and there to pass the winter, germinating the next spring. On leaf surfaces of its host plant Sadebeck* has germinated the



67.—*Cross section of a part of a leaf affected with leaf-curl, showing the fruiting of the fungus. (From Bulletin 73, by Professor Geo. F. Atkinson.*

spores of a closely related species growing on Alnus. This took place, apparently, soon after the spores were produced. It is hoped that some studies now under way will throw light upon this important matter,—important because treatment can be made more effective the more complete is our knowledge concerning time and method of infection. At present, the results from preventive treatments indicate that normal infections take place in the spring.

d. Conditions Affecting the Abundance of the Leaf-Curl.

The sporadic occurrence of the leaf-curl is rather remarkable. In many sections of the State there was very little in 1896. The

*Unters. über d. Pilzgattung Exoascus, u. d. durch dieselbe um Hamburg hervorgerufen Baumkrankheiten. Abgedruck a. d. Jahrb. d. Wiss. Anst. p. 102, 1883, Hamburg.

same sections in 1897 saw a large increase in the abundance of the disease, and the past season was characterized by unusual injuries from this cause. This wave of increasing abundance during the past few years seems to have extended quite generally through the Northern States, judging from inquiries received, and from the activity of experimenters in this field of work at various experiment stations.

Attempts have been made specifically to define the conditions which encourage the curl. Some have asserted that a cool, moist spring is most conducive to its abundance. The time of infection, however, should be determined, it seems, before any satisfactory explanation may be given. It is quite reasonable to suppose that the conditions prevailing at the time the spores of the fungus are being disseminated, or the conditions prevailing at the time the spores germinate to infect the buds or leaves would be the factors to determine the greater abundance or the less abundance of the disease the following year. If the spores of the fungus live over winter on the ground or twigs, and germinate with the first warm days of spring to infect the opening buds, then the spring conditions would seem to be of great importance in determining the amount of the disease. If, however, infections result during summer or autumn the effect of spring conditions is not apparent.

It is well known that different varieties of the peach show different degrees of susceptibility to the attacks of leaf-curl. The same is often found to be true of other plants attacked by other fungous diseases, and it can only be explained by constitutional differences in the varieties. Among varieties of peaches very susceptible to the curl, Selby* mentions Mountain Rose, Old Mixon, Globe, Elberta, Scott's Nonpareil, Red Cheek, and others. Such a list will, in all probability, vary with the place, and I have examined some orchards of many varieties in which none were exempt.

e. Remedies.

The early experiments made to determine the value of fungicides for the prevention of peach curl were unsatisfactory both

* Bulletin 92, Ohio Agricultural Exp. Station, 1898.

68.—*Photograph showing rows 2 and 3; row 2, on the right, sprayed early with Bordeaux mixture; row 3, on the left, sprayed late with Bordeaux.*

because the fungicides themselves often injured the leaves, and also because the best time for spraying was not apparent from our knowledge of the fungus. Much of the later work has been to demonstrate that spraying one season lessons the disease during the succeeding season. At the time that my experiments were begun, I was not aware of other results.

In an orchard of young trees closely set and used for some experiments with borers, by M. V. Slingerland, leaf-curl appeared in 1896. The following year it was so abundant as to cause almost entire defoliation, and there was every promise of an abundant reappearance of the disease in 1898. These trees were so close together that they were especially desirable for such work, since it would be very probable that any remedy proving more or less effective under such conditions would be even more effective under ordinary circumstances. There was also the additional advantage that the trees were all known to have been affected the previous year. Several varieties were represented in the orchard, and the experimental rows were run across varieties, so as to eliminate any error on this score.

The treatments given, and dates of spraying, were as follows :*

Row 1. Check.
2. Bordeaux mixture, April 8, May 10, May 21, June 8.
3. Bordeaux mixture, May 10, May 21, June 8.
4. Bordeaux mixture, April 8, Potassium sulfide, May 10, May 21, June 8.
5. Check.
6. Potassium sulfide, May 10, May 21, June 8.
7. Bordeaux mixture, April 8, Ammon. copper carbonate, May 10, May 21, June 8.
8. Ammon. copper carbonate, May 10, 21, June 8.

In the statement of results the abundance of the disease the previous year must be remembered, for it is very evident that no hope could be entertained for securing exemption from the disease where the fungus had been carried over winter in the twigs.

*In this experimental work Mr. H. P. Gould coöperated with me.

Notes on the results at the different dates may be stated thus:

Apr. 8.—Buds hardly beginning to swell. (1st spraying.)

May 10.—Soon after pollination of the flowers; petals dropping, and young leaves out from one-half to one inch long. Even at this time a large number show that the curl is present, by increased reddish coloration, but almost no distortion of surface. Microscopic examination showed that there was yet no fruiting of the fungus. (2d spraying.)

May 21.—Curl showing abundantly in the orchard both on leaves and twigs; fungus not yet fruiting. (3d spraying.)

June 1.—Row 1, (check). Very bad; almost every leaf on the tree affected.

Row 2, (Bordeaux early). Very good, curl mostly confined to some of the tips of growing twigs.

Row 3, (Bordeaux late). Very bad; almost every leaf affected.

Row 4, (Bordeaux early, Potas. sulf. late). Very good; perhaps slightly more curl than in row 2.

Row 5, (Check). Very bad; almost every leaf affected.

Row 6, (Potas. sulf. late). Very bad; a large majority of the leaves affected.

Row 7, (Bordeaux early, Am. cu. carb. late). Very good; almost equal to No. 2.

Row 8, (Am. copper carb. late). Very bad; almost every leaf affected.

Particular attention should here be directed to the fact that where Bordeaux mixture was used before the buds swelled, the foliage of the trees was very largely entirely free from the curl, even during this first year of treatment; and this was true irrespective of the mixture subsequently used (compare rows 2, 4, and 7). Unfortunately, there was no row which received the first treatment only.

June 8.—On this date, the time of the last application, the leaves badly affected were falling abundantly. Soon after this time the photograph was taken from which figure 68 is reproduced. This figure shows the difference between the row sprayed late with Bordeaux, and the row sprayed both early and late with Bordeaux, rows 2 and 3.

The final results indicate very significantly that at most there is very slight effect from the treatments subsequent to the early treatment with Bordeaux, and that the early treatment is the one of importance for the protection of the foliage during the same year. Perhaps the subsequent treatments may prove of value as to the amount of the curl the following year, and this is what others have already demonstrated.

69.—*A branch from a tree in row 2, sprayed early with Bordeaux mixture.*

Since securing these results, I have had correspondence with some orchardists who had sprayed peach trees for various diseases. With few exceptions, those who have sprayed early have been those successful in the prevention of the curl.

A very interesting result has been reported by Mr. A. I. Loop of North East Penn. So far as the prevention of curl is concerned, the benefit was accidental; but the value of early spraying is again demonstrated. From his letter, I quote as follows, "The experiment was to try the effect of whitening for the protection of buds during winter. The directions given by Professor Whitten in his bulletin issued at Columbia, Mo., were followed. A selection was made about the center of a block of 4000 trees; about a dozen trees across the rows, including different varieties, were treated. The first application was made

the first week in January, using his regular milk and lime formula. The next was the same treatment on the first of February. They were again treated about the first of March, but instead of milk we used dextrine. * * * As to results,—we could discover no difference in time of blossoming between the treated and untreated trees. * * * We discovered one thing, however, that we thought remarkable. All of our trees were considerably affected with curl-leaf, but we found these treated trees to be almost absolutely free from it. At least one-half of these trees have not shown a single diseased leaf up to the present time (July 27) ; about one-half of them had one or two diseased leaves. The adjoining trees on both sides and on each end of the treated trees without exception showed many curled leaves, from 25 per cent to 75 per cent of all of the leaves on the trees being affected."

The above is very conclusive, even with a fungicide, dilute whitewash, which we have not held in high esteem when used alone. For this early treatment it has one of the special advantages of Bordeaux mixture, that of adhering well.

In the Year Book of the U. S. Dept. of Agriculture, 1897, page 110, there are given some noteworthy figures concerning the gains which growers on the Pacific coast have enjoyed by following out certain lines of treatment suggested by the Department. This report was not out until our experiments were practically complete, and in it no statement is made of the time when the applications were made. I have since learned, however, that special stress is laid upon the early spraying. The results at other experiment stations, notably at Ohio, largely confirm what has already been said concerning remedies.

Special recommendations :—With our present knowledge of peach leaf-curl, the following may be suggested :

1st. Spray thoroughly with strong Bordeaux mixture just previous to the swelling of the buds, late in March, or very early in April seems desirable in this latitude.

2d. Spray again with weaker Bordeaux as soon as the petals of the flower have fallen, or after the work of the bees is over.

3d. Spray again with weak Bordeaux when the first leaves are just full grown, or at just about the time that the spores of the fungus are developing.

Discussion of recommendations :

1st. Why not spray in midwinter ? Midwinter spraying may be quite effective, but there is every reason to believe that the April spraying will be better ; for if that is near the time that the buds are infected, the spores will then be more readily killed. If a time when other work is not pressing is of first importance, spray earlier. Why not use copper sulfate solution? It may be quite as efficient, but Bordeaux adheres better and would be more likely to prevent infections throughout a period.

70.—*A branch from a tree in row 3 sprayed late with Bordeaux mixture.*

2d. Why? Late infections by spores from the ground or from neighboring fields may thus be guarded against.

3d. This spraying is to cover the leaves with Bordeaux at about the time the fungus is fruiting, hoping not only to prevent summer infections, but to cover places where the spores may lodge in order to pass the winter.

The Bordeaux Mixture.

In making the first spraying, the all-important one, strong Bordeaux mixture may be used ; and every twig should be so well covered that the blue color appears as a distinct coating after

the application has dried. However, under certain conditions, the foliage of the peach seems to be easily injured by spraying with Bordeaux mixture. With weak Bordeaux mixture properly made, I have not been able to produce any injury on the trees experimented upon.

The customary formula for Bordeaux mixture is :

Copper sulfate (blue vitriol)..... 6 lbs.
Unslaked lime (good quality)..... 4 lbs.
Water.....50 gallons.

In spraying the foliage of peach trees, reduce the copper sulfate to four pounds. Even this may seem strong. It should not, however, be condemned until tried; and when tried the mixture should be made by the one method which has been most successful.* To dissolve the copper sulfate, suspend it in a coarse sack in a barrel containing twenty-five gallons of water. Slack the lime (use only the best) slowly, and then dilute it to twenty-five gallons. Pour the two together in this dilute form, stirring for a few minutes. Stir before using. If large quantities of the mixture are desired, stock solutions may be made as usual. Dissolve say fifty pounds of the copper sulfate in a barrel containing as many gallons of water. The stock solution of lime may be made of the same strength. Then each gallon means a pound of the substance wanted. When the mixture is made, dilute each solution separately before pouring them together.

*See *Farmers' Bulletin* No. 38, U. S. Dept. Agriculture, p. 6.

II. NOTES ON THE SHOT-HOLE EFFECT OF PEACHES AND PLUMS.*

During several years past I have received from a few correspondents, leaves of the plum and of the peach badly affected

71—*Shot-hole effect on Japan plum sprayed with improperly made Bordeaux mixture.*

with a shot-hole injury. The interesting feature of the cases mentioned was the fact that this injury occurred where the trees

*Fuller details upon this subject will be found under the same title in the Proceedings of the Soc. for Promotion of Agl. Sci., 1898.

had been abundantly sprayed. From observations already made, I had suspected that other causes besides the shot-hole fungus might be responsible for some of the troubles referred to me. In one case, especially, there was an unusual appearance of the shot-hole effect in a large orchard soon after the application of Bordeaux mixture.

On the horticultural grounds of the Experiment Station, during the season of '97, Mr. H. P. Gould called my attention to the abundance of the shot-hole effect on Japan plums which he had sprayed constantly. I had then completed some experiments with the production of such injuries by means of substances injurious to the foliage; and the results indicated clearly that injuries to the foliage by many deleterious chemical agents might produce the characteristic shot-hole appearance.

It was reasonable to believe that spraying might have the same effect under certain conditions. Later experiments were made to test the effect of some copper compounds upon the foliage of the peach and of the apricot, and comparatively upon plums of the native, domestica, and Japan groups. In general the peaches, apricots, and plums of the native and domestica groups were free from any shot-hole effect; but the Japan plums generally indicated some injuries of this kind. The entire orchard had been sprayed with Bordeaux mixture tested with potassium ferrocyanide. A few trees of each kind mentioned were then sprayed with properly prepared Bordeaux mixture, with Bordeaux mixture containing an excess of copper, with Bordeaux made by the use of poor lime, and with a solution of copper sulfate containing one pound of the compound to about 15 gallons of water.

The properly prepared Bordeaux produced no injury except upon the Japan plum (Burbank); but there was an evident injury in the latter case. The improperly made Bordeaux mixtures affected the peach and the Japan plum to a marked extent, a photograph of injuries to the latter being shown in figure 71. By the same mixture the apricot and the native plum (Yellow Transparent) were somewhat injured, while the effect upon the domestica (Empire) was scarcely noticeable. The copper sulfate solution of course produced injury in all cases, but this injury was very little in the case of the domestica, and somewhat more pro-

nounced with the native. On the Japan plum and on the apricot a marked shot-hole effect was produced, followed by considerable

72.—*Shot-hole effect on peach produced by weather conditions.*

defoliation, and on the peach there was complete defoliation within a few days.

The shot-hole effect abundant among Japan plums in the orchard was again examined, but there was no indication of a causal fungus; and very significant was the fact that young

shoots growing out beyond the region covered by the spraying were wholly free from such injuries. There was no doubt that this general appearance of a shot-hole fungus on the Japan plums was due directly to the spraying. An unsprayed orchard of Burbank and Abundance in the vicinity showed no shot-hole injury whatever.

Later experiments on the Chabot plum confirmed the previous work, indicating that under certain conditions the Bordeaux mixture may be injurious to the foliage of the Japan plums, much more so, in fact, than to that of the peach.

Among the varieties which have shown the greatest injury from spraying during the past season may be mentioned, Willard, Chabot, Douglass, Berckmans, Earliest of All, Georgeson, Ogon Kelsey, Blood No. 3, and Abundance. Burbank and Red June were also affected. Forest Garden was the only native plum noticeably affected, and all varieties of the domestica group were conspicuously free from the trouble.

An examination of specimens of the various fungi affecting the peach and the plum will show that, with the exception of leaf-curl, mildew, and a few others, these fungi are very generally productive of a shot-hole effect. The fungus most abundant in a particular region will be the one there designated as a shot-hole fungus. With these facts at hand, my experiments with fungicides and other chemical agents above referred to were made. These results are sufficient to demonstrate that this shot-hole effect is a peculiar physiological reaction of the plant to injuries of many kinds.

Figure 72 shows an effect of this kind produced by peculiar causes. The tree was blown down during a summer rain storm. The rain was followed by a hot, steaming afternoon; and in about two days the shot-hole effect was evident.

After an examination of a number of plum orchards in this State, I find the Japan plums so free from shot-hole fungi that I see no necessity of spraying them for these particular diseases and thus encouraging a shot-hole effect due to spraying.

Where the plum rot is bad, it will be necessary to spray, and one must disregard the slight injuries to the foliage resulting from the use of properly made Bordeaux mixture.

B. M. DUGGAR.

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155. Second Report on the San José Scale.
156. Third Report on Potato Culture.
157. Grape-vine Flea-beetle.
158. Source of Gas and Taint Producing Bacteria in Cheese Curd.
159. An Effort to Help the Farmer.
160. Hints on Rural School Grounds.
161. Annual Flowers.
162. The Period of Gestation in Cows.
163. Three Important Fungous Diseases of the Sugar Beet.
164. Peach Leaf-Curl.